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Tall Fescue and Smooth Bromegrass. I. Nitrogen and Water Requirements[1]

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ABSTRACT

Irrigated cool-season grasses are needed in the Southern High Plains to extend grazing provided by winter wheat (*Triticum aestivum* L.) pasture and native range. Little information is available concerning their N requirements in relation to irrigation water application. The main objective of this study was to determine the N and water requirements for sustained high production of tall fescue (*Festuca arundinacea* Schreb.) and smooth bromegrass (*Bromus inermis* Leyss.). 'Fawn' tall fescue and 'Southland' smooth bromegrass were grown on Pullman clay loam (fine mixed thermic, Torrertic Paleustoll) under fertilizer N rates of 0, 168, 336, 504, and 672 kg ha^{-1}year^{-1} on three water regimes. The N source was NH_4NO_3 except in a companion study in which feedlot manure was used.

In one year of the 3-year study when all irrigation treatments could be compared, adequately watered (W-2) and fertilized (672 kg N/ha) tall fescue yielded 15.2 metric tons/ha, whereas similarly treated smooth bromegrass yielded 12.0 metric tons/ha. With moderate water (W-1) and adequate N, however, smooth bromegrass yielded 6.9 and tall fescue yielded 5.2 metric tons/ha. With moderate water distributed for cool-season forage production (W-3), respective yields of similarly fertilized tall fescue and smooth bromegrass were 11.9 and 10.9 metric tons/ha. Also in 1976, first cuttings produced 77, 62, and 82% of total seasonal yields on W-1, W-2, and W-3 plots, respectively.

Over the 3-year period, yield increases were almost directly proportional to the amount of N applied through 336 kg/ha. Yield increases per kg of applied N (to 336 kg/ha) were 12.1, 24.1, and 17.9 kg on W-1, W-2, and W-3 plots, respectively. Feedlot waste, at N rates equivalent to those applied as NH_4NO_3, was about one-half as efficient as NH_4NO_3 in increasing yields.

In the Southern High Plains, the most efficient irrigation management for tall fescue and smooth bromegrass is for early spring production with subsistence irrigation for the rest of the year.

Additional index words: *Festuca arundinacea* (Schreb.), *Bromus inermis* (Leyss.), Forage yields, Fertilizer N uptake, Water-use efficiency, Southern High Plains, Feedlot waste.

IN the Southern High Plains, forages are needed to provide year-round grazing for dairy cows and for replacement cattle for feedlots. Combinations of native grass pastures, wheat, (*Triticum aestivum* L.), and summer annuals provide grazing except for the period from about mid-March, when cattle should be removed from wheat pasture, until late May, when native grass pastures have grown enough for grazing. During this period, the production from cool-season grasses such as tall fescue (*Festuca arundinacea* Schreb.) and smooth bromegrass (*Bromus inermis* Leyss.) is at its highest, and these grasses are being utilized to a limited extent. Little information is available, however, on their N and water requirements in this region.

In a study of irrigated grasses in Colorado, at five N rates, tall fescue outyielded smooth bromegrass at all except the highest N level (717 kg N/ha) (2). At this level, yields of both grasses approached 9 metric tons/ha. In western South Dakota, Hanson et al. (6) determined the forage yield responses and N recovery of irrigated smooth bromegrass to single and split N applications. The first application was in March, and, for split applications, the second was after first harvest. Both forage yields (11,800 kg/ha) and N recovery by bromegrass (52%) were highest from a total of 448 kg of N/ha in split applications. In North Dakota, Lorenz et al. (9) studied how moisture levels and fertilizer rates affected smooth bromegrass yields. Yields increased significantly from both irrigation and fertilization. In Georgia, Hallock et al. (5) obtained maximum tall fescue yields from 448 kg N ha^{-1}year^{-1} in the mountain region, but in the southern Piedmont region, yields increased 2 metric tons/ha when N was increased from 448 to 896 kg of N ha^{-1}year^{-1}.

The purposes of our study were to determine (i) the N and water requirements for sustained high forage production from tall fescue and smooth bromegrass and (ii) the efficiency of N in animal waste as compared with inorganic N fertilizer for forage production of these cool-season grasses.

MATERIALS AND METHODS

The experiment was conducted on Pullman clay loam (fine, mixed, thermic Torrertic Paleustoll) at the USDA Conservation and Production Research Laboratory, Bushland, Texas. The site had been dry farmed for about 40 years, usually to winter wheat. No fertilizer had ever been applied; however, the soil contained significant plant-available N. Initial NO_3^--N was not measured but accumulations of about 200 kg/ha have been measured in the surface 1.8 m of similarly managed Pullman clay loam (3). In the main experiment 'Fawn' tall fescue and 'Southland' smooth bromegrass were grown under five rates of N and three irrigation regimes. The N rates were 0, 168, 336, 504, and 672 kg ha^{-1}year^{-1} as ammonium nitrate (NH_4NO_3). In a companion study, animal waste from a cattle feedlot was applied at rates of 336 and 672 kg of N ha^{-1}year^{-1}. The three irrigation regimes were W-1, a moderate (about 50-cm) and W-2, an adequate (about 100-cm) irrigation water level, both distributed for season-long production and W-3, a moderate (about 60-cm) irrigation level distributed for cool-season forage production. The companion study with animal waste received irrigation treatment W-2.

The main experiment was conducted in a randomized block split-split plot design with three replications. The main plots were level border plots that were flood irrigated through gated pipe. Water was measured with a low-pressure line meter. Irrigation treatments occupied main plots (9 × 46 m), grass species occupied subplots (4.5 × 46 m) and fertilizer treatments occupied sub-subplots (4.5 × 9 m). The companion study occupied two level border plots adjacent to the main experiment.

The amounts of water applied and received as precipitation before and between harvests, and fertilization and harvest dates

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Table 1. Dates of fertilizer applications and harvests, amounts of irrigation water applied, and precipitation received before and between harvests during 1974 through 1976.

W-1 & W-2		W-3			Irrigations		
Fertilized	Harvested	Fertilized	Harvested	Precipitation	W-1	W-2	W-3
				cm			
1974							
3/19	5/16	3/19	5/16	4.0	25.4(2)†	25.4(2)	25.4(2)
5/21	7/1	-	7/1	12.6	12.7(1)	25.4(2)	-
7/5	8/30	-	-	22.1	12.7(1)	25.4(2)	12.7(1)
9/4	11/8	9/4	11/8	14.2	-‡	12.7(1)‡	12.7(1)‡
Total				52.9	50.8	88.9	50.8
1975							
3/19	5/16	3/19	5/16	5.8	22.9(2)§	22.9(2)	22.9(2)
5/22	7/1	-	7/1	9.0	12.7(1)	22.9(2)	-
7/8	8/11	-	8/11	13.0	10.2(1)	22.9(2)	12.7(1)
8/11	10/29	8/18	10/29	3.6	12.7(1)	35.6(3)	35.6(3)
Total				31.4	58.5	104.3	71.2
Midwinter irrigation (12/5)					12.7	12.7	12.7
1976							
3/18	5/24	3/18	5/24	10.2	12.7(1)	22.9(2)	22.9(2)
6/2	7/19	-	-	7.8	12.7(1)	25.4(2)	-
7/21	9/8	-	-	7.0	12.7(1)	25.4(2)	12.7(1)
9/9	11/9	9/9	11/9	9.4	12.7(1)	22.9(2)	22.9(2)
Total				34.4	50.8	96.6	58.5

† Numbers in parentheses after irrigation amounts are the number of irrigations in which the water was applied. Also, all treatments were irrigated alike before the first harvest in 1974 to ensure vigorous stands. ‡ One irrigation withheld due to precipitation.
§ "Midwinter" irrigation applied 13 February is included in irrigation applied for first harvest. That and one more irrigation on 30 April were enough on all irrigation treatments. Thus, there was no difference among irrigation treatments for the first harvest in 1975.

are presented in Table 1. The amount of water applied at each irrigation was either 10.2 or 12.7 cm. Usually, the soil surface was so dry that 12.7 cm of water was required for uniform coverage of plots, however, at some irrigations, uniform coverage was obtained with 10.2 cm and applications were limited to that amount. At individual irrigation dates, all plots irrigated received like amounts of water.

After the grasses were planted in September 1973, they were uniformly sprinkler-irrigated to establish stands. On W-1 and W-2 plots, one-fourth of the fertilizer was applied at the beginning of the growing season and the subsequent one-fourth increments were applied after the first, second, and third harvests. On W-3 plots, one-half of the fertilizer was applied at the beginning of the growing season and the other half was applied on the date of the fourth application on W-1 and W-2 plots (Table 1). Where animal waste was the N source, the total annual application was made at one time. The first year, it was broadcast and rototilled into the soil before planting. After that, it was surface-applied at the beginning of the 1975 and 1976 growing seasons. Animal waste applications were based on total N content according to the Kjeldahl method (1). Enough waste was applied to give the desired total N rates. The N contents of the waste applied in the fall of 1973 and the spring of 1975 and 1976 were 1.5, 2.38, and 2.45%, respectively.

Forage was harvested with a flail-type plot harvester at a height of 5 cm (3.2-m² sample in 1974, 7.2-m² sample thereafter). After yield samples were taken, residual areas were harvested with a tractor-drawn field chopper. On irrigation treatments W-1 and W-2, forage was harvested when the grasses headed in the spring (tall fescue was fully headed, smooth bromegrass was partially headed) and then three more times at about 6-week intervals. Grasses on W-3 plots were scheduled to be harvested only twice annually, at times corresponding to the first and fourth harvests on the other irrigation treatments. However, they were harvested three times in 1974 and four times in 1975. Because in both 1974 and 1975 there was regrowth after first harvests that would have been lost by the scheduled second harvest, they were harvested at the second harvest of W-1 and W-2 plots. In 1975, they were also harvested at the third harvest of W-1 and W-2 after a 5.2 cm rain on 23 July and the scheduled irrigation on 1 August allowed some regrowth. Dates of all harvests of all treatments are given in Table 1. Yield samples were oven dried (55 C) to obtain dry weights. Subsamples were ground in a Wiley mill and analyzed for total N by the Kjeldahl method (1) modified to include nitrate.

In the main study, soil water was measured on the plots to which 336 kg of N/ha was applied, and in the companion study, it was measured on the plots to which 672 kg of N/ha was applied. Soil water was measured by the neutron method to a depth of 3 m in 30-cm increments at two locations per main plot. It was measured when growth began in the spring, before each irrigation, and after the final harvest each year. Water use for a given period was determined by summing the change in soil water content, the irrigation water applied, and the precipitation received during the period. Water-use efficiency (WUE) was determined by dividing dry matter yield (kg/ha) by water use (cm).

Residual NO_3^--N was measured in the upper 2 m of soil after the final harvest each year. Samples were taken at 33-cm depth increments from three locations per fertilizer plot (fescue plots only) and composited by depth increments. Nitrate-N was extracted by 0.1 *N* KCl and determined with an autoanalyzer (8).

RESULTS

Yields of both grasses were higher in 1974 than in 1975 and 1976 (Table 2). The decreases in annual yields after 1974 were due to yield decreases in the second, third, and fourth harvests (Fig. 1). At first harvests, yields on well-fertilized treatments did not decline over the 3-year period. The higher yields at second, third, and fourth harvests in 1974 may have been due to summer rainfall (Table 1) and the accompanying more favorable summer temperatures. The average daily maximum temperatures in August and September 1974 were 27.4 and 22.5 C—4.4 and 6.3 degrees below the long-time average. One might suspect that a plant nutrient deficiency, possibly P, was responsible for the decrease in yields after the first year. Since the study did not include a P variable

Table 2. Annual yields of tall fescue and smooth bromegrass as affected by irrigation and fertilizer treatments.

Treatment		1974		1975		1976		Average	
Irrigation	N	Fescue	Bromegrass	Fescue	Bromegrass	Fescue	Bromegrass	Fescue	Bromegrass
	kg/ha	metric tons/ha							
W-1	0	10.3	10.0	3.4	3.1	1.5	1.5	5.0	4.9
	168	13.0	12.5	5.2	5.9	3.7	3.0	7.3	7.1
	336	14.5	15.3	6.5	8.0	4.9	5.0	8.6	9.4
	504	16.4	15.5	7.3	10.5	5.2	6.4	9.6	10.8
	672	16.4	15.9	8.1	9.9	5.2	6.9	9.9	10.9
W-2	0	9.1	8.2	2.9	2.6	1.7	0.8	4.6	3.9
	168	14.9	13.6	8.2	5.2	7.1	4.1	10.1	7.6
	336	16.3	16.3	11.3	10.2	11.7	8.4	13.1	11.6
	504	17.8	17.8	14.2	11.3	13.6	10.8	15.2	13.3
	672	21.3	19.8	14.4	12.2	15.2	12.0	17.0	14.7
	336M†	9.9	7.6	6.8	4.4	5.9	3.6	7.5	5.2
	672M	16.5	13.5	12.0	9.0	11.7	7.6	13.4	10.0
W-3	0	9.6	10.0	2.1	2.3	2.0	1.5	4.6	4.6
	168	11.8	11.8	5.6	7.0	7.2	7.0	8.2	8.6
	336	14.1	14.3	7.7	8.4	10.1	9.2	10.6	10.6
	504	15.5	15.9	8.6	9.7	10.2	10.6	11.4	12.1
	672	16.2	15.3	10.0	10.0	11.9	10.9	12.7	12.1
	L.S.D. (0.05)	2.2		1.3		1.4		1.2	

† Nitrogen applied as feedlot waste.

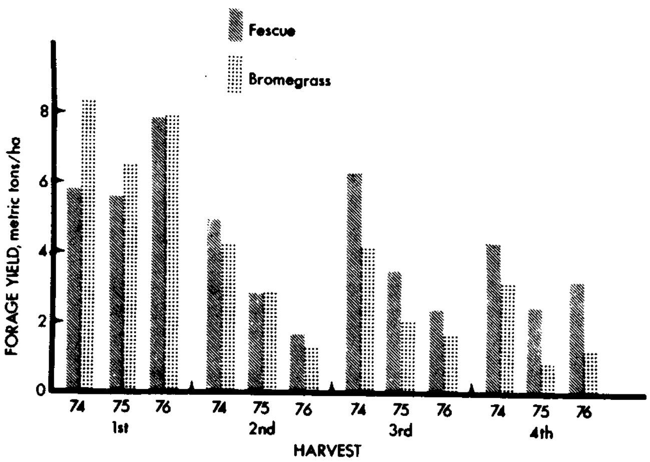

Fig. 1. Forage yields of tall fescue and smooth bromegrass at four harvest dates in 1974, 1975, and 1976 (W-2 irrigation treatment, 672 kg of N/ha).

and P was not applied to the experimental site, we cannot definitely state that P was not limiting; however, the following evidence indicates that yields were not limited by P deficiency: (a) feedlot waste treatments did not outyield NH_4NO_3 treatments at first harvests (data not shown). Also, (b) results obtained in a related greenhouse study (unpublished data) indicated that P probably was not limiting in the field; and (c) previous fertilizer experiments with field crops have shown that Pullman silty clay loam contains enough P and K for maximum production of grain crops (7, 11).

Species Effects

Average annual forage yields for the study (averaged for irrigation treatments W-1 and W-2 and for all N treatments) show that tall fescue, at 10 metric tons $ha^{-1}year^{-1}$, outyielded smooth bromegrass by almost 1 metric ton $ha^{-1}year^{-1}$ (Fig. 2). These data show that smooth bromegrass outyielded tall fescue at first harvests, but that tall fescue outyielded smooth bromegrass at all subsequent harvests. Analyses of yield data by harvests and years showed that smooth bromegrass significantly outyielded tall fescue at two of the three first harvests (1974 and 1975) whereas tall fescue significantly outyielded smooth bromegrass at all other harvests but the third in 1975 and the second in 1976.

Nitrogen-fertilized tall fescue generally outyielded smooth bromegrass with adequate (W-2) but not with moderate (W-1) water (Table 2). The more competitive yield of smooth bromegrass for the W-1 treatment resulted from greater yields of smooth bromegrass than tall fescue at the first harvests.

Nitrogen Effects

Even though the pre-existing high soil N level caused 1974 yields on the unfertilized and low N treatments to be somewhat higher than those obtained from similar N treatments in 1975 and 1976, and the irrigation treatment on W-1 differed among years, N response curves were similar each year. Thus, the 1974 to 1976 average yields were used in Fig. 3. Yields were almost directly proportional to the amount of fertilizer N applied in treatments of 0 through 336 kg N/ha. Yields continued to increase as the amount of N applied exceeded 336 kg/ha, but the rate of increase per unit of applied N decreased. Yield increases per kg of applied N to 336 kg/ha were 12.1, 24.1, and 17.9 kg on W-1, W-2, and W-3 plots, respectively. Smooth bromegrass was especially responsive to the additional N.

Yields from the plots where 336 and 672 kg N/ha was applied as feedlot manure were about equal to those from plots where NH_4NO_3-N was applied at rates of 168 and 336 kg/ha, respectively (Table 2). Apparently, about one-half of the N applied in ma-

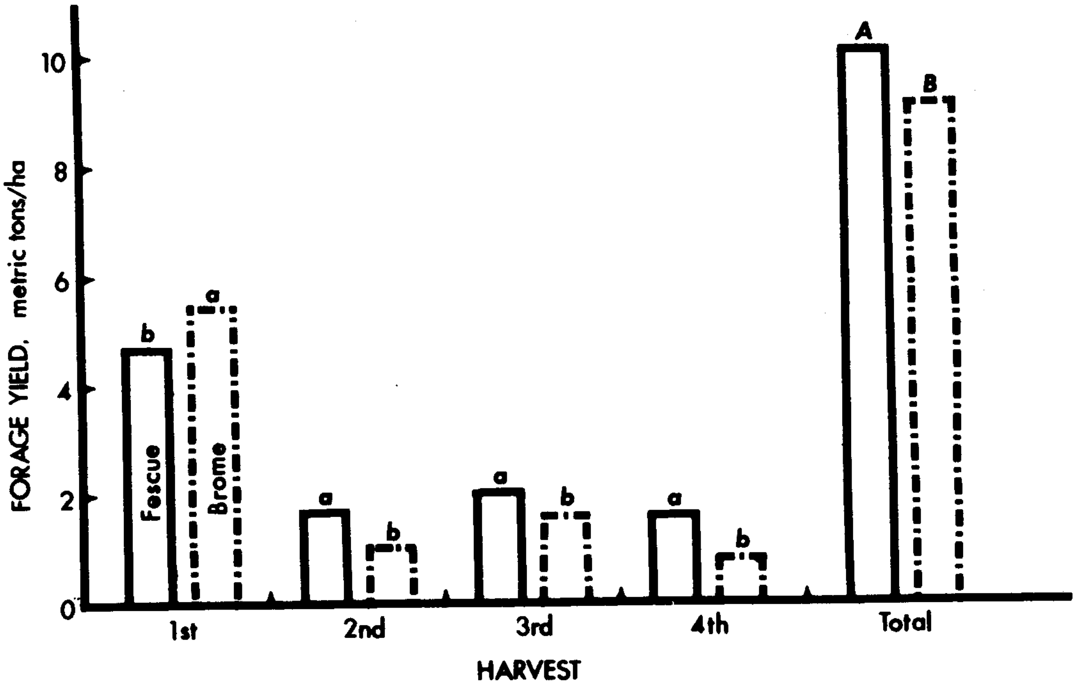

Fig. 2. Forage yield by harvests averaged over irrigation treatments 1 and 2 and over all N treatments 1974 to 1976. Within harvests, bars with the same small letter on top are not significantly different at the 5% level. Bars with the same capital letter on top are not significantly different at the 10% level. (Differences based on the Duncan Multiple range test.)

nure was available to the crop. This is consistent with calculations by the equation of Mathers and Goss (10). They found that percent N was the main factor in controlling the decay rate of manure and that amount of manure (M) required to supply 100 kg N/ha could be calculated by the equation

$$M = \frac{445.2 - 234.7\,(\ln \%\, N)}{10\,(\%\, N)}\; t^{\,(0.3254\,(\ln \%\, N) - 0.5057)}$$

where t is time in years. Using this equation with the amounts and N contents of manure applied, we found that on the plots at the 672-kg N/ha rate, 192, 335, and 374 kg of plant-available N/ha was furnished by the manure in 1974, 1975, and 1976, respectively.

Irrigation Treatment Effects

All irrigation treatment plots were watered alike before the first harvest in 1974 and 1975. In 1974, the second irrigation was applied to ensure uniform stands on all plots. In 1975, the midwinter irrigation was delayed until February, and W-2 and W-3 treatments required only one additional irrigation, which was applied to all plots on 30 April. Consequently, season-long data are available for comparison of all three of the irrigation treatments only for 1976 (Fig. 4). These data showed that in 1976 W-1 and W-3 treatments yielded 50 and 94% as much forage as W-2, respectively, and that the first harvest on W-1, W-2, and W-3 plots produced 77, 62, and 82% of total seasonal yields, respectively. The 3-year average yields for W-2 and W-3 treatments (11.10 and 9.54 metric

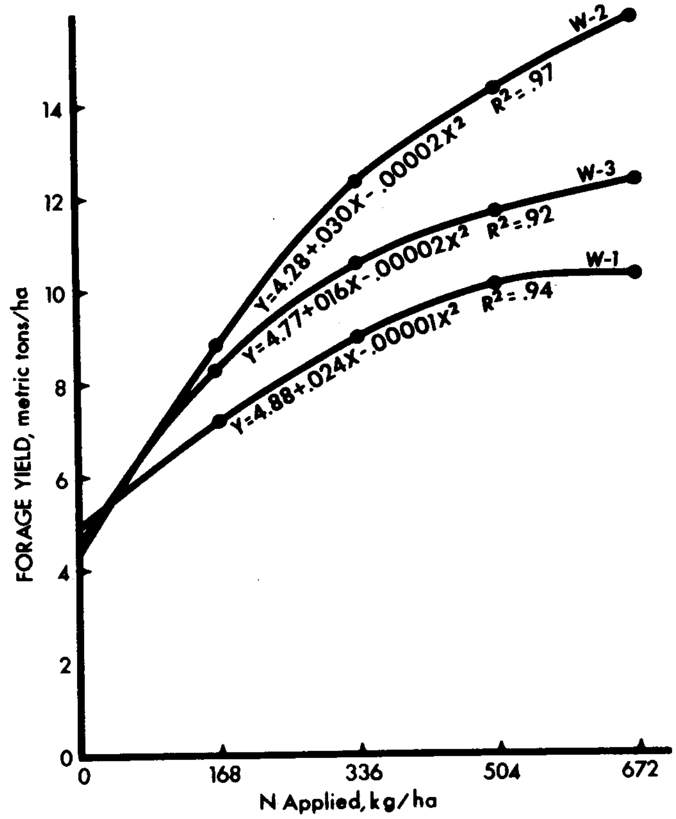

Fig. 3. Forage yields as affected by irrigation and fertilizer treatments. Average of tall fescue and smooth bromegrass yields, 1974 to 1976.

tons/ha, respectively) showed that the W-3 treatment yielded about 86% as much forage as the W-2 treatment.

Water-Use Efficiency

Since soil water was measured only in plots fertilized with 336 kg N/ha, WUE was calculated using yields from these plots. Also, because species did not significantly affect soil water content, the soil water data from the two measurement locations per main plot were averaged. Thus, the differences in the WUE of the two grasses shown in Table 3 are directly proportional to differences in their yields. When W-3 plots were harvested more than twice each year (three times in 1974, four in 1975), data after the first harvest were summed and the WUE calculated as though there had been only two harvests. In 1974, the extra harvest may have increased measured yields, and thus increased the end of season WUE somewhat because part of the early regrowth might have been lost if it had not been harvested before the end of the season. In 1975, the extra harvests may have decreased yields, and thus decreased the end of season WUE somewhat, because the third harvest was only about 18 days after a 5.2-cm rain broke drought dormancy. The plants may not have produced as much forage in two growth periods as they would have in one. Due to the higher yields at first harvest each year and to the lower evaporation potential in the spring, WUE was much higher at first harvest than later (Table 3). Although as much water was available for the regrowth harvests as for the first harvest, yields (and thus WUE) were lower. Water-use efficiency varied among regrowth harvests and no definite trends were evident.

Annual WUE (average of grasses) was similar on the three irrigation treatments in 1974 and 1975 when all treatments received similar irrigations before first harvests, but in 1976, when the W-1 plots were irrigated only once before the first harvest, WUE was higher on the W-2 and W-3 than on the W-1 plots. There were trends (although not significant) toward higher WUE on W-3 than on W-2 plots in 1974 and 1976.

N Uptake and Fertilizer N Recovery

Uptake of N, expressed as the percentage of N applied, is given in Table 4. On W-1 and W-3 plots, N uptake was greater by smooth bromegrass than by tall fescue, but on W-2 plots, the reverse was true. The greater N uptake by tall fescue on W-2 plots resulted from the greater tall fescue forage yield on that treatment. The N content of smooth bromegrass was greater than that of tall fescue (4), but tall fescue yields were enough greater than those of smooth bromegrass to offset the differences in N content.

Dotzenko (2) measured uptake of fertilizer N under soil moisture and N rates similar to those on W-2 plots. At 179 kg N/ha, with smooth bromegrass, he measured recovery similar to ours, but with tall fescue, his recovery was lower. In addition, as his rates of N increased, he found that recovery decreased, whereas our recovery on W-2 remained essentially constant at all N rates through 676 kg N/ha, the highest we tested.

The calculations of uptake of fertilizer N from the animal waste treatments (Table 4) were based on total N applied. Since only part of the total N applied in manure became available during the study, it is better to base the calculations on the amount of N

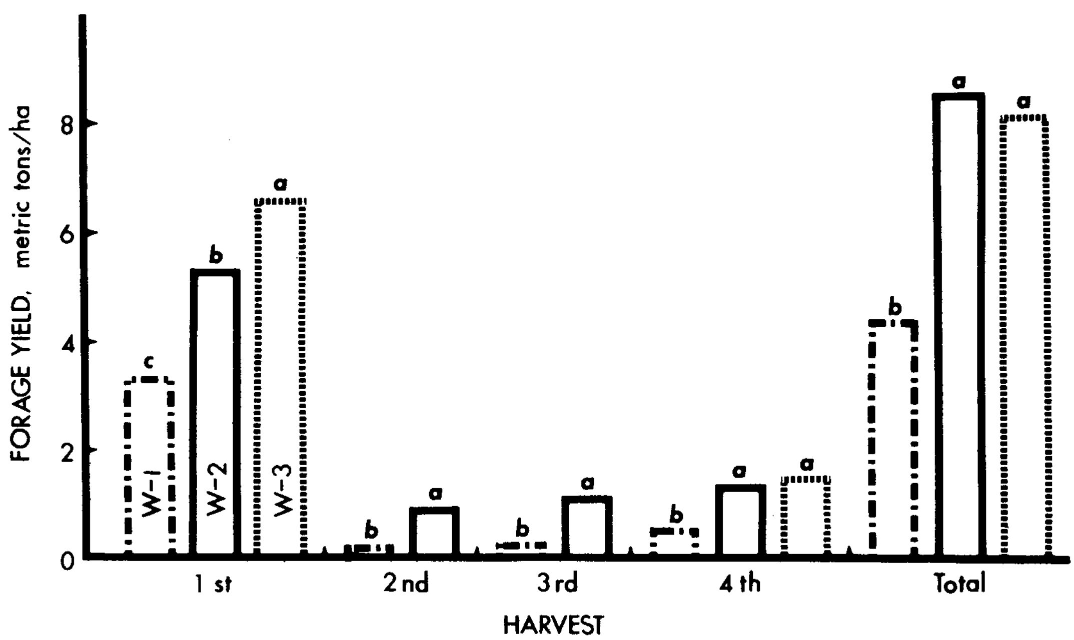

Fig. 4. Forage yields by harvest as affected by irrigation treatments. Average of tall fescue and smooth bromegrass yields in 1976. Within groups, bars with the same letter on top are not significantly different at the 5% level. (Differences based on Duncan Multiple range test.)

Table 3. Yield and water-use efficiency (WUE) of tall fescue and smooth bromegrass at each harvest as affected by irrigation treatments (W-1, W-2, and W-3). Data from the 336-kg of N/ha treatment.

	W-1				W-2				W-3			
	Fescue		Brome		Fescue		Brome		Fescue		Brome	
Harvest	Yield	WUE	Yield	WUE	Yield	WUE	Yield	WUE	Yield	WUE	Yield	WUE
	kg ha^{-1}	kg ha^{-1} cm^{-1}	kg ha^{-1}	kg ha^{-1} cm^{-1}	kg ha^{-1}	kg ha^{-1} cm^{-1}	kg ha^{-1}	kg ha^{-1} cm^{-1}	kg ha^{-1}	kg ha^{-1} cm^{-1}	kg ha^{-1}	kg ha^{-1} cm^{-1}
1974												
1	5,850	194 cd*	8,010	263 ab	4,890	149 d	7,320	223 abc	6,640	202 bcd	8,650	262 ab
2	2,430	76 ab	1,890	59 b	3,770	91 a	3,330	80 a				
3	3,710	147 a	3,560	133 a	4,200	110 a	3,320	87 a				
4	2,560	165 a	1,810	116 bc	3,450	133 ab	2,310	88 cd	7,440	103 bcd	5,640	78 d
Annual	14,550	139 A*	15,270	145 A	16,310	117 A	16,280	122 A	14,080	134 A	14,290	136 A
1975												
1	4,080	142 c	5,560	194 a	4,830	169 b	5,640	199 a	4,920	142 c	5,860	170 b
2	770	35 b	480	22 b	2,310	78 a	2,290	78 a				
3	1,270	63 ab	1,890	92 a	2,360	63 ab	1,700	39 a				
4	390	13 b	70	3 b	80	43 a	520	12 b	2,780	36 a	2,550	33 a
Annual	6,510	66 C	8,000	82 A	11,280	82 A	10,150	74 B	7,700	68 BC	8,410	74 B
1976												
1	3,560	230 c	4,170	270 bc	6,890	294 ab	5,610	240 c	7,810	317 a	7,700	313 a
2	240	15 b	220	13 b	1,320	47 a	840	34 ab				
3	250	10 b	180	7 b	1,270	30 a	1,120	26 a				
4	870	36 b	400	17 c	2,200	75 a	820	28 bc	2,320	40 b	1,460	24 bc
Annual	4,920	61 C	4,970	61 C	11,680	103 AB	8,390	75 BC	10,130	122 A	9,160	111 AB

* Within harvests, means followed by the same lower case letters are not significantly different at the 5% level of significance based on the Duncan Multiple range test. Within years, means followed by the same capital letters are not significantly different at the 5% level of significance based on the Duncan Multiple range test.

Table 4. Uptake of fertilizer N, residual N level, and N recovery as affected by irrigation and fertilizer treatments.

Treatment		Average uptake of fert. N†, 1974–76		Residual NO_3^--N, 1976
Irrigation	N	Fescue	Brome	(Fescue only)
	kg/ha	%		kg/ha
W-1	0			10
	168	36.3	34.2	20
	336	37.4	44.0	53
	504	34.2	45.0	488
	672	29.7	38.1	1042
W-2	0			11
	168	65.1	46.6	8
	336	62.7	61.6	11
	504	58.2	54.8	9
	672	56.9	55.7	152
	336M‡	16.8(37.6)§	7.5(16.9)	7
	672M	28.2(63.2)	21.7(48.6)	7
W-3	0			11
	168	51.0	76.9	15
	336	56.7	60.8	88
	504	46.1	56.1	444
	672	42.5	45.0	1254
L.S.D. (0.05)		13.7		210

† Percent uptake of fertilizer N =

$$\frac{(\text{N yield fertilized} - \text{N yield unfertilized}) \times 100}{\text{Fertilizer N applied}}$$

‡ Nitrogen applied as feedlot waste.

§ Values in parentheses are calculated on the basis of the amount of N estimated to become available from the waste rather than from the total N applied.

estimated to become available from the waste. On that basis, uptake of N by tall fescue from the low and high rates of animal waste were 37.6 and 63.2%. Respective values for smooth bromegrass were 16.9 and 48.6%. These values, except for the 63.2% uptake from the high waste rate for tall fescue, indicated that uptake of available N from waste was less efficient than that from NH_4NO_3. However, no definite conclusion can be made, because the amount of available N from waste was estimated. Determinations made in 1974 showed that N levels were similar under the two grasses, so smooth bromegrass plots were not sampled for residual NO_3^--N in 1976. The final residual NO_3^--N levels for tall fescue (Table 4) showed that no NO_3^--N accumulated in the soil on W-2 plots from N levels as high as 504 kg/ha but some accumulated from the 672-kg/ha treatment. On W-1 and W-3 plots, some NO_3^--N accumulated from the 336-kg of N/ha treatment, and much more accumulated from the 504- and 672-kg of N/ha treatments.

The greater accumulation of residual N on W-3 than on W-2 cannot be attributed solely to differences in forage yields. It is possible that more N was leached from the root zone or was denitrified on the wetter treatment. Also, the differences in time of application of N may have favored N accumulation on the W-3 treatment.

DISCUSSION

Both tall fescue and smooth bromegrass produced most of their annual growth in the spring when grazing was needed. In addition, WUE was highest during spring. At later harvests, especially those in midsummer, growth and WUE were comparatively low. The W-1 irrigation treatment was not satisfactory; WUE was very low after the first harvest, and in addition, the treatment did not supply forage continuously. During summer, the grasses grew for about 3 weeks after an irrigation and then dried up and became dormant. The W-2 irrigation treatment was more satisfactory than W-1 in that it supplied forage continuously, but with this treatment also the WUE was low after the first harvest. Because these grasses produce poorly during the hot part of the year and produce more efficiently in early spring when they are needed most, it would be most efficient to manage them for early spring production and allow them to remain dormant or semidormant for the rest of the year. Our W-3 irrigation treatment, which approached this management, did not improve WUE significantly. However, our observations indicated that one or possibly two fall irrigations could be skipped without injuring the stand and potential for early spring production. If these irrigations could be skipped, WUE would be considerably increased.

Management for early spring production with later dormancy would be compatible with irrigation in the region. The principal irrigated cash crops in the area are grain sorghum [*Sorghum bicolor* (L.) Moench] and corn (*Zea mays* L.), which require water during the summer. Thus water would be available for grass in the fall and spring. There is not enough water to irrigate all of the irrigable land in this region. Therefore, many farmers have land that might be best utilized only for spring grazing when WUE is highest.

In management for early spring production, the N fertilizer should be applied in late winter when the grass starts to grow. Our data from irrigation treatment W-3 indicated that an N rate of about 336 kg/ha would give near-maximum yields. Under management for season-long production with full irrigation (W-2), 336 kg of N/ha did not produce as much forage as 504 or 672 kg of N/ha, but it did produce a good yield of better quality forage (5) and more forage per kg of applied N. Depending on quality requirements and economics, a proper N rate for season-long production might range from 336 to 504 kg/ha.

Although either grass would respond to management for early spring production, smooth bromegrass might be chosen on the basis of its higher yields at first harvest and its higher N content. If grass tetany is a concern, however, tall fescue might be the better choice (4). If managed for season-long use, tall fescue would be better because of its higher yields during the hot part of the summer.

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